MULTIMEDIA UNIVERSITY ™

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023

ETM7126 – SATELLITE COMMUNICATIONS

(All sections/Groups)

8 FEBRUARY 2023
9:30 a.m. – 12:30 p.m.
(3 hours)

INSTRUCTION TO STUDENT

1. This examination paper consists of **7 pages** (including the cover page) with **4 questions only.**
2. Total marks for the questions is **100 marks. Attempt ALL parts of the question.**
3. Please write all your answers. **Show all relevant steps** to obtain maximum marks.

Question 1

(a) Describe how geosynchronous orbit operates in the satellite communication system.
[6 marks]

(b) List out SIX (6) disadvantages of satellite operating at highly elliptical orbit.
[3 marks]

(c) Molniya orbit is a highly elliptical orbit in satellite communication system, which named after a series of Soviet/Russian Molniya communications satellites. The orbital parameters for a Molniya orbit are listed in Table Q1(c) below.

Table Q1(c)

Period	11hours 58minutes 2seconds
Inclination	63.45°
Eccentricity	e
Apogee altitude	39105 km
Perigee altitude	A_p
Visibility duration	> 8 hours

(i) Calculate the length of semi major axis of the orbit, a.
[2 marks]

(ii) Determine the eccentricity, e and perigee altitude, A_p.
[4 marks]

(iii) Determine the mean true anomaly, M of a satellite on the Molnya orbit after 5 minutes the passage of perigee.
[2 marks]

(iv) List TWO(2) disadvantages of this orbit.
[2 marks]

(d) Determine the period and linear velocity the space shuttle with a circular orbit at the height, h of 1000 km.

(Note: Take radius of the earth, r_{earth} of 6378 km, and gravitational parameter, $\mu = 3.986004418 \times 10^5 \text{km}^3 s^{-2}$)

[6 marks]

Continued...

Question 2

(a) What is a cross polarization in antenna? Discuss the application of vertical, horizontal and circular polarization in a satellite system.

[8 marks]

(b) The block diagram of a 12 GHz satellite uplink with the following parameter is shown in Figure 2(b). The transmitted power is 10 watts. The diameter of both the transmitting and receiving parabolic antennas is 3 m with an efficiency of 55%. The satellite is placed in a geostationary satellite orbit (GSO).
Note: Take the distance of the GSO from the earth surface is 35 900 km.

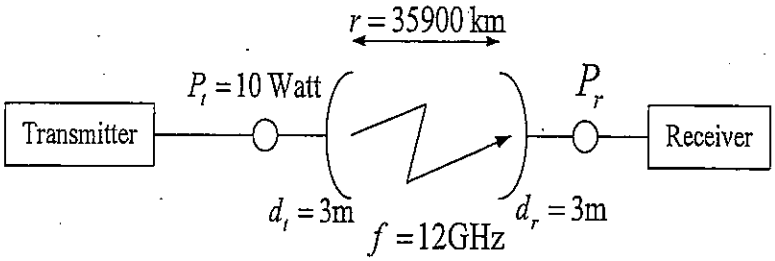

Figure 2(b)

Determine the following:

(i) Antenna gain in dBi.

[3 marks]

(ii) Effective isotropic radiated power (EIRP) in dBw.

[1 mark]

(iii) Free space loss in dB.

[1 mark]

(iv) Isotropic received power in dBw.

[2 marks]

Continued...

(c) Figure 2(c) shows the satellite receiver noise system with specific parameters given for each device. The low noise amplifier (LNA) has a gain of 30 dB, and a noise figure of 4 dB. The LNA is connected to the downconverter through a 3 dB line loss cable. The downconverter has a gain of 10 dB and a noise figure of 10 dB. Finally, the signal passes through an I.F. amplifier with a gain of 40 dB, and a noise figure of 20 dB. All the noise figures shown in the circuit are with effective temperature of 290 K.

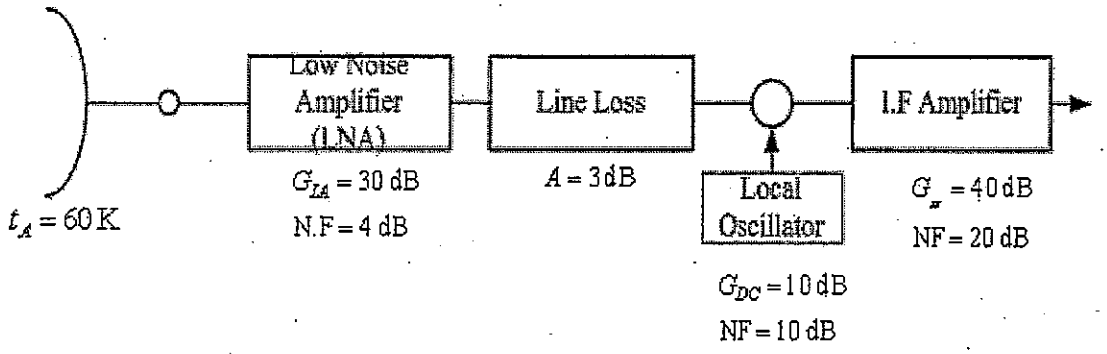

Figure 2 (c)

(i) Construct an equivalent noise circuit to represent the receiver.

[2 marks]

(ii) Determine the total noise temperature and noise figure.

[6 marks]

(iii) Calculate noise power spectral density.

[2 marks]

Continued...

Question 3

(a) Explain with an aid of diagram, why it is necessary to employ single-sideband suppressed-carrier (SSB-SC) in a satellite communication system.

[6 marks]

(b) In demand assigned multiple access (DAMA), the methods of allocating the capacity required to set up a call can be divided into centralized control and distributed control. Distinguish between both control systems.

[5 marks]

(c) In a speech signal, the lowest frequency is 300 Hz and the highest frequency, f_m is 3.4 kHz. Consider a Single Channel Per Carrier - Frequency Modulation - Frequency Division Multiple Access (SCPC-FM-FDMA) system with a specific Channel Signal to Noise Ratio (SNR) of 33 dB. Let the test tone peak frequency deviation be $\Delta f = 9.1$ kHz. Determine:

(i) the bandwidth of the SCPC-FM-FDMA system.

[3 marks]

(ii) the carrier-to-noise ratio of the SCPC-FM-FDMA system.

[4 marks]

(d) Consider a 70-channel frequency duplex multiplexing (FDM) system with a maximum baseband frequency of 252 kHz and a specified top channel SNR of 50 dB. Assume that FDM multichannel root mean square of frequency deviation, lf_r = 500 kHz is employed.

Determine:

(i) the bandwidth of the Frequency Duplex Multiplexing- Frequency Modulation-Frequency Division Multiple Access (FDM-FM-FDMA) carrier using Carson's Rule.

[2 marks]

(ii) the FDM multichannel loading factor of n=70 channels.

[2 marks]

(iii) the 0 dBm test tone rms frequency deviation.

[1 mark]

(iv) the Carrier to noise ratio of the FDM-FM-FDMA system in dB. Assume channel bandwidth of 3.1 kHz and psophometric weighting of 6.5 dB.

[2 marks]

Continued...

Question 4

(a) Explain why on board processing is required in multibeam satellite system.

[6 marks]

(b) Provide FIVE(5) requirements in 5G satellite mobile communications system.

[5 marks]

(c) In satellite communication, there are several factors that affect the handover of satellite station. Suggest the handover types for each of the following scenarios.

- Scenario 1
  - Movement from one spot beam to another
  - mobile station still in the footprint of the satellite, but in another cell
- Scenario 2
  - Movement from one satellite to another satellite
  - mobile station leaves the footprint of one satellite
- Scenario 3
  - Movement from one gateway to another
  - mobile station still in the footprint of a satellite, but gateway leaves the footprint
- Scenario 4
  - Movement from the satellite network to a terrestrial cellular network
  - mobile station can reach a terrestrial network again which might be cheaper, has a lower latency.

[8 marks]

(d) Consider a multibeam satellite system with M spot beams. The total bandwidth B is divided into 4 subbands. Subband 1 is used 6 times, subband 2 is used 4 times, subband 3 is used 3 times and subband 4 is used 3 times. Calculate:

(i) the re-use factor if no orthogonal polarisation is used.

[2 marks]

(ii) the re-use factor if orthogonal polarisation is used.

[2 marks]

(iii) Comment on the results obtained above.

[2 marks]

End of Questions

APPENDIX I

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^8 m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right)A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

Free space loss, $L_{FS} = \left(\dfrac{4\pi R}{\lambda}\right)^2$

$\left[\dfrac{C}{N_0}\right] = [EIRP] + \left[\dfrac{G}{T}\right] - [L] - 10\lg(k)$, noise power spectral density $N_0 = kT$.

$$\frac{N_0}{C} = \left(\frac{N_0}{C}\right)_U + \left(\frac{N_0}{C}\right)_D + \left(\frac{N_0}{C}\right)_{IM}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(g l \Delta f_{rms} + f_{max})$, where $\log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$

$$\left[\frac{C}{N}\right] = \left[\frac{S}{N}\right] + 10\lg\left(\frac{b}{B}\right) + 20\lg\left(\frac{f_{\max}}{\Delta f_{rms}}\right) - [P] - [W]$$

Appendix II: Table of Complementary Error Function

$$erfc(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt \quad \text{for } 0 \le z \le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

For $z > 4$, $erfc(z) \approx \frac{1}{\sqrt{\pi}} \left(\frac{e^{-z^2}}{z} \right)$

End of Paper